



Notes on the natural history and morphology of the Ningshan Lined Snake (*Stichophanes ningshaanensis* Yuen, 1983; Ophidia: Colubridae) and its distribution in the Shennongjia National Nature Reserve, China

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Abstract.—The present study reports on the natural history of the Ningshan Lined Snake (*Stichophanes ningshaanensis*) in the Shennongjia National Nature Reserve (NNR) in western Hubei Province, China. Prior to this work, little was known about the natural history of this species due to a paucity of specimens since the original description in 1983. Since its discovery, only the original three specimens were known to science, all of which are now lost or destroyed. Over the course of five summers, we observed 24 specimens within the Shennongjia NNR. We report on its natural history, including seasonal activity, habitat and environmental preferences, breeding behavior, sexual dimorphism, and incubation data for the eggs. We reiterate the morphological differences between *Stichophanes*, its former genus *Oligodon*, and members of Pareatidae. In China, *Stichophanes* is not protected under law due to the species being classified as “Data Deficient.” The species exhibits sexual dimorphism and dichromatism, i.e., males are smaller than females and the sexes differ in color. The species has unique breeding habits in mid-summer, and copulation occurs immediately after oviposition of the females. The number of eggs per clutch ranges from eight to nine, and takes 64 days to hatch.

Key words. *Oligodon*, *Pareas*, Asia, slug eaters, reproduction

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Little is known about the Ningshan Lined Snake, *Stichophanes ningshaanensis* Yuen, 1983. The species was discovered in Ningshan County, Shaanxi Province, China, in the southern part of the Qinling Mountains (Yuen 1983) and was described based on three specimens, which presently are all lost or destroyed (Wang et al. 2014). No additional specimens were found until in 2006 a survey revealed 17 new specimens in Shennongjia NNR, western Hubei Province (Yang et al. 2009). In the original description, the species was assigned to family Colubridae and placed in the genus *Oligodon*. But few of its morphological characters match up to the genus, additionally, none of the characters fit easily into any other Asia genera. It was for this reason the species was recently assigned to the new genus *Stichophanes*

(Wang, Messenger, Zhao, and Zhu 2014). The specific epithet *ningshaanensis* is named for Ningshan County in Shaanxi Province (note the double “aa” in the specific epithet, which is not a typo and distinguishes Shaanxi Province from Shanxi Province. In this circumstance, it is used to correctly pronounce the extended vowel sound of Shaanxi compared to Shanxi in the Mandarin language), where the type specimen was found. The generic epithet *Stichophanes* breaks down into *stichos-* (Greek), meaning “line or row,” and *-phanes* (Greek), meaning “appearing, conspicuous,” in reference to the dorsal and lateral lines of the body.

Due to its elusive behavior, and the paucity of specimens, little was known about the natural history of the species. Aside from the initial description, the only other

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work of the species was an examination of the microstructure of the skin by Li and Liang (2007), which revealed a canaliculated type structure. Additionally, prior to the 2006 field work, this snake was among the rarest of China's species, with only three specimens known to science at the time. Even though the species is locally common at select locations within Shennongjia NNR, this species could very well be a species of conservation interest if no additional populations are found in its range. For these reasons, it is important to understand the natural history of the species.

This study reports on the natural history, breeding ecology, and distribution of the species as observed in the Shennongjia NNR, and additional commentary on aspects of its unique morphology, with special regard toward the genus *Oligodon* and members of the family Pareatidae.

Materials and Methods

Fourteen field sites were surveyed within the Shennongjia NNR in western Hubei Province, China (Fig. 1). Approximately one week was spent at each field station. At field stations, the primary surveying technique was walking habitat day and night, flipping natural cover objects

such as rocks and logs, and actively searching using visual and auditory stimuli. The first survey was conducted in 2006 from May to September. A second survey was completed in July 2008. A final intense survey was carried out during the summer of 2011. Beginning in 2012, only one month every summer was surveyed opportunistically.

If the reserve museum did not have a specimen, then an animal was preserved as a voucher. Subsequent individuals were photographed and released unless they differed from the previous specimens in such attributes as pattern, gender, or age. Specimens were deposited with the museum officials in Shennongjia, headquartered in the town of Muyu. Specimens were later relocated to the research lab at Guanmenshan within the reserve. Locations of finds were marked with GPS coordinates (accuracy < 3 m). Environmental data such as ambient temperature, substrate temperature, habitat, and elevation were recorded as well as precipitation and time of day or night.

Upon capture, each animal was sexed via probing and measured snout-to-vent (SVL) and total length (TL) to the closest 0.25 cm using a tape measure. Measurements of eggs were taken with digital slide calipers to the closest 0.01 mm. Dorsal scale rows were counted one head length posterior to the head, at mid-body, and one head-length distance anterior to the vent.

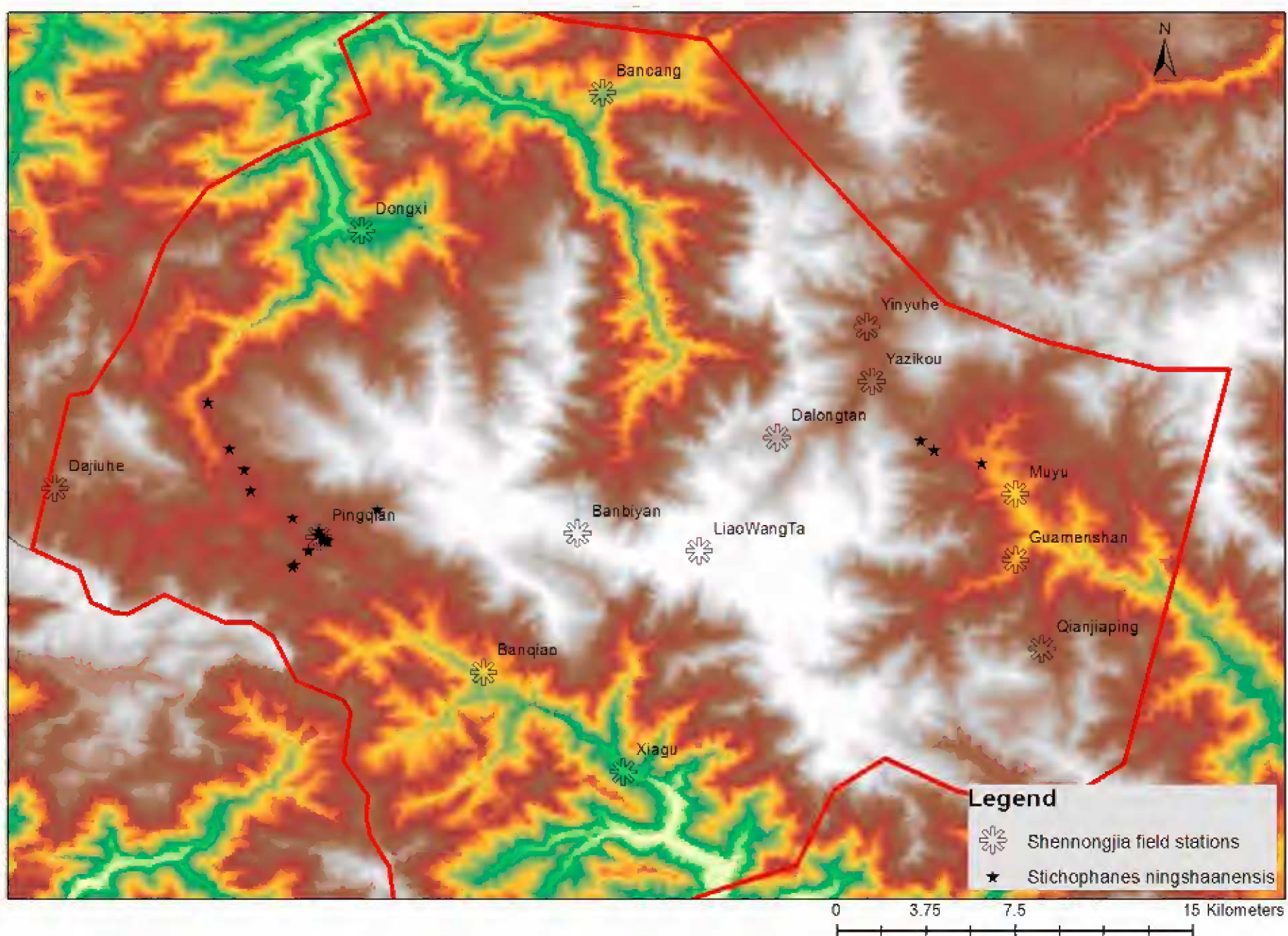


Fig. 1. Locations of field stations and of *Stichophanes ningshaanensis* ($n = 22$) within the Shennongjia NNR.

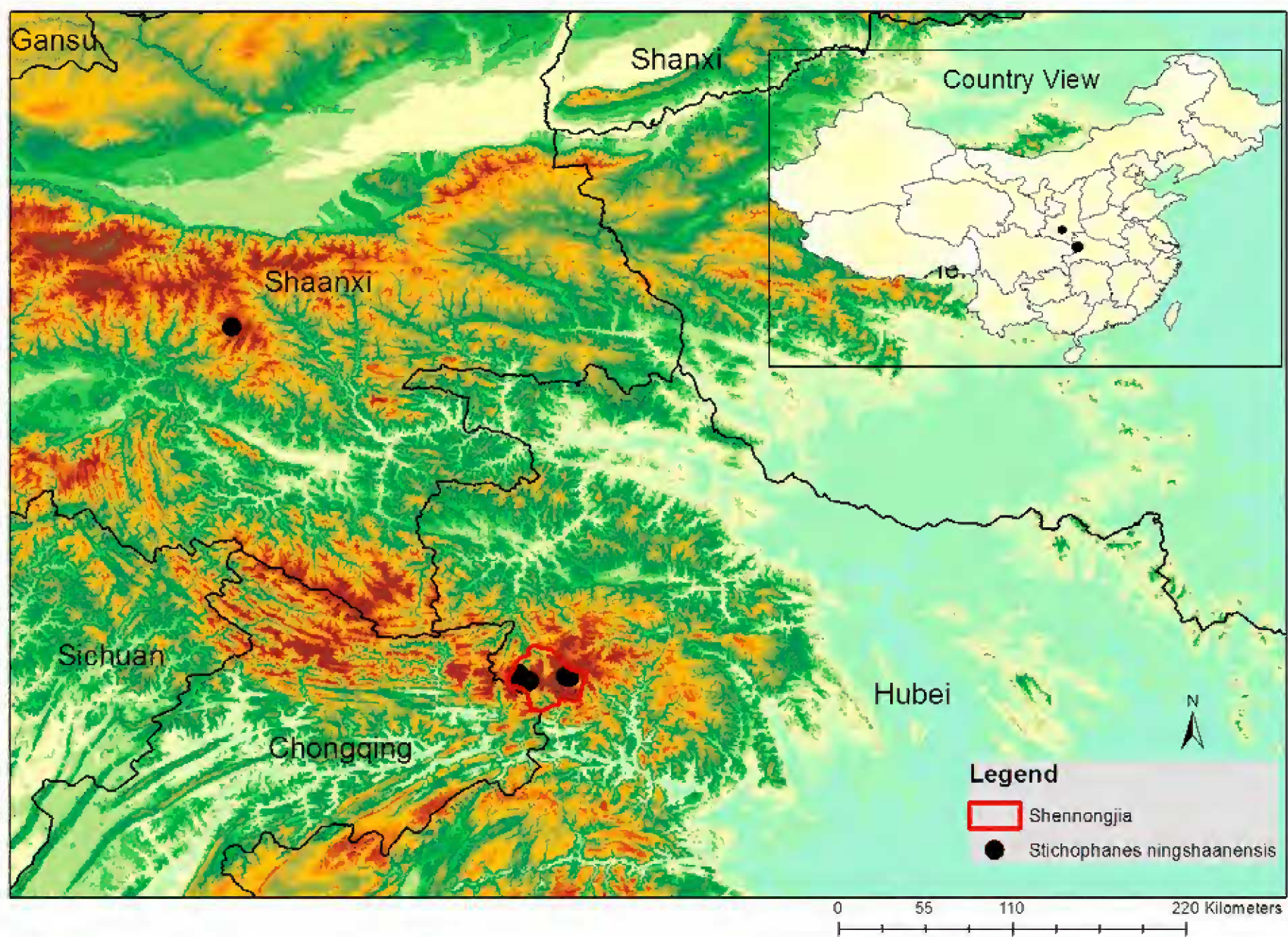


Fig. 2. Current known range of *S. ningshaanensis*; type locality located in Shaanxi province.

Results

From 24–26 June 2006, we found six females and three males near Pingqian. Three of the females were dead (one beat to death by villagers, two were road kill); all males were alive. In July 2008, we found eight live specimens, and one dead specimen, all adults except one sub-adult. Three new locations within the reserve were recorded: a high mountain road near the town of Xiangshui, another record between the towns of Banqiao and Pingqian, and several individuals ($n = 3$) on the outskirts of Muyu. In July 2011, we found an additional three specimens in Pingqian and another on the mountain road near Xiangshui (N31.531231° E110.113914°). In the years 2012–2014, no additional new locations were discovered. In 2012, we had a single observation, representing the earliest known observation of the species since its discovery in 1983. In 2012, surveys were conducted in late May, early June, and early August. In 2013, major construction and development at the core site, Pingqian, began, and only a single specimen was found in July, ironically crossing habitat just bulldozed. The year 2014 represented the first year that surveys failed to find an individual, despite surveying during the active time of year for the species. The development started in 2013 was much more extensive in 2014 and much of the habitat in

Pingqian, where individuals had been found previously, was completely destroyed or urbanized.

The finds in Shennongjia NNR represented a range extension of 280 km to the southeast of the type locality, and the first major population found since the species' discovery in 1983 (Yang et al. 2009; Fig. 2).

Description Based on Specimens from Shennongjia NNR

Dorsal scales are smooth, with counts of 13, 13, and 12 anteriorly, mid-body, and posteriorly, respectively. The anal scale is divided. Head scales consist of two post-oculars, one pre-ocular, no loreal scale, six supralabials (3rd and 4th in contact with eye), five infralabials, one anterior temporal, and two (sometimes one) posterior temporals. The rostral scale is smooth and not upturned or protruding as is characteristic of the genus *Oligodon*. The subcaudal scales are paired.

Males are olive-brown or olive-green, and females are yellow-brown in color. In both sexes, the venter is a cream-colored version of the dorsal background color. Both sexes have a single row of dots on the lateral edges of each ventral scale. These spots tend to fade posteriorly. Anteriorly, there are five distinct black lines immediately posterior to the head. One line is along the spine



Fig. 3. Close up of the head, showing detail of the scales, and illustrating the indistinct neck of the species. Photo by Kevin R. Messenger.

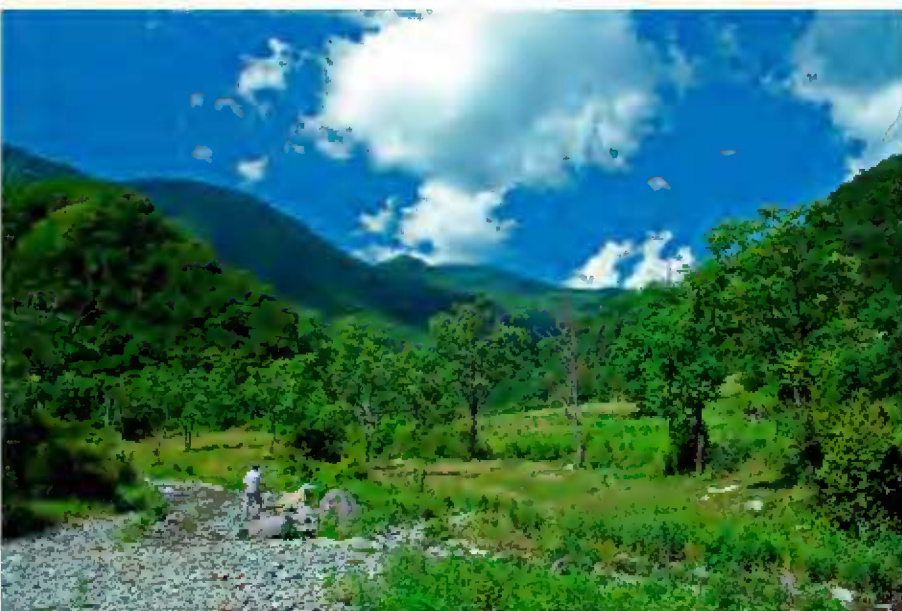


Fig. 5. Typical habitat of *Stichophanes ningshaanensis* in the Pingqian area pre-2013. Photo by Kevin R. Messenger.

but quickly fades from black to brown to indistinct and blending with the background coloration toward the tail. Two pairs of lines are situated dorso-laterally and run the length of the body with consistent boldness, often the inferior edge of the line is brown and the superior edge remains black. The final two pairs of lines are located ventro-laterally, between or along the 1st and 2nd scale rows. The iris is golden-brown in females and golden-yellow in males. The head is indistinct from the neck (Fig. 3).

The largest individual found was a female measuring 730 mm total length (TL) and 578 mm Snout-to-vent length (SVL). The largest male measured 654 mm TL and 495 mm SVL. Hatchlings ($n = 17$) averaged 150 mm TL (SD + 4 mm) and 119 mm SVL (SD + 2 mm).

Natural History Notes

Specimens were found during the day and in the evening, as late as 80 minutes after sunset. Twenty four specimens were found: locals beat one specimen to death, two were found dead on the road, two specimens were under rocks, and the rest were actively moving about. Species observations were primarily terrestrial, but lacking specimens outside the breeding season, species are suspected to be primary fossorial and only move above ground during

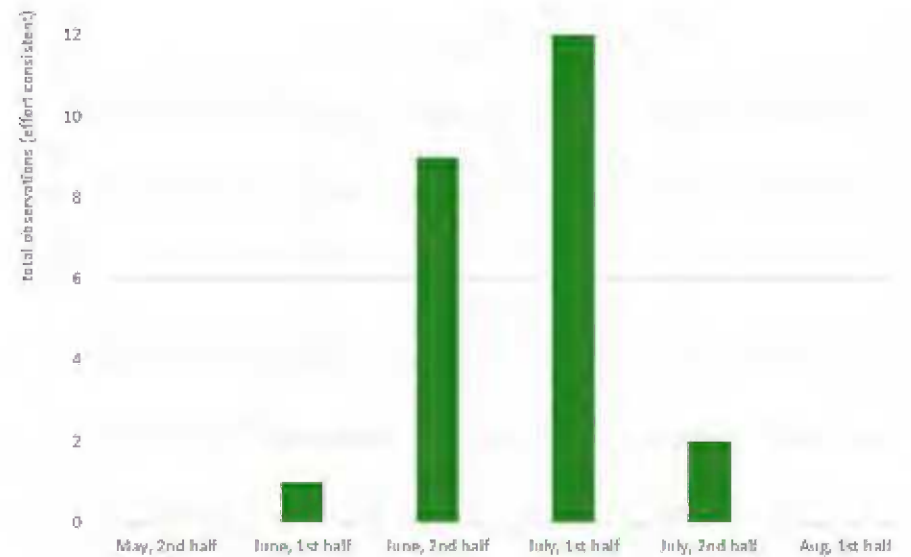


Fig. 4. Seasonal activity of *Stichophanes ningshaanensis* observations ($n = 24$).

the breeding season. No specimens were found in an arboreal setting. During the breeding season, several specimens ($n = 8$) were also found dead on the road. The average elevation of provenances of specimens was 1628 (SD + 126 m) (range 1,550–2,200 m). May surveys failed to find specimens. The earliest observation date was a female found on 07 June 2012, but in general, late June and early July were best times finding species as this is the breeding season and snakes were actively moving above surface (Fig. 4). The latest documented date occurrence was on 20 July 2008. Surveys in August and September failed to detect any specimens. The species was usually in proximity to water, i.e., within ~300 m of a water source, and was often encountered actively moving after rainstorms. The species was active on overcast and cool days with temperatures ranging 20–24 °C.

With respect to habitat, between 1,500–2,600 m elevation, the habitat is classified as temperate deciduous broadleaf coniferous forest including Farges' Fir and Fortune's Rhododendron (Zhao et al. 2005). Average annual temperature of locations where individuals were found were 16.2 °C (range: 15.6–16.7). Average annual precipitation of locations where individuals were found was 222.85 mm (range: 209–235). Individuals were found in ephemeral stream beds, in short grasses, commonly found on the outskirts of agriculture land, and in habitat adjacent to permanent streams (Fig. 5). Individuals were never far from a source of water.

Stichophanes ningshaanensis shares its habitat with the following species: Snakes: *Achalinus spinalis*, *Azemioops feae*, *Dinodon* [=Lycodon] *rufozonatum*, *Elaphe carinata*, *Lycodon* cf. *fasciatus*, *Orthriophis taeniurus*, *Protobothrops jerdonii*, *Pseudoxenodon macrops*, *Rhabdophis nuchalis*, *Sibynophis chinensis*; Lizards: *Plestiodon capito*, *P. elegans*, *Scincella modesta*, *Sphenomorphus indicus*, *Takydromus septentrionalis*; Anurans: *Amolops chunganensis*, *A. granulosus*, *Bufo* cf. *andrewsi*, *Megophrys wushanensis*, *Odorrana margaratae*, *Paaquadranus*, *Rana chensinensis*; Salamanders: *Liua shihi* and *Ranodon tsinpaensis* (pers. obs.).

When confronted, the species was reluctant to bite. No amount of provocation elicited a defensive bite.



Fig. 6. Tail-curling defensive behavior characteristic of *Oligodon*: *O. formosanus* (left), *O. ornatus* (right), and enlarged rostral scale. Photos by Kevin R. Messenger.



Fig. 7. Courtship behavior by the male, rubbing his chin along the female, observed on 28 June 2006. Photo by Kevin R. Messenger.



Fig. 8. Courtship behavior by the male observed on 28 June 2006, and illustration of dichromatic differences. Photo by Kevin R. Messenger.

Many members of *Oligodon* effectively use their unique teeth when restrained and harassed and will bite readily. *Stichophanes* thrashes about and readily produces musk but does not display the characteristic tail-coiling known to some other species within the genus *Oligodon* (Seshadri 2014; Fig. 6).

Notes on Reproduction

The species exhibits strong sexual dimorphism, not only in size, but also in color (sexual dichromatism), an uncommon trait among snakes (Boulenger 1913; Jacob and Altenbach 1977; Shine and Madsen 1992). There are only a handful of other species that have been reported to exhibit sexual dichromatism, such as *Crotalus lepidus klauberi*, in which males have a greenish hue and females have a purple hue (Jacob and Altenbach 1977). Shine and Madsen (1992) noted dichromatism in the genus *Vipera*. In *S. ningshaanensis*, males are smaller than females. Females are yellowish-brown, while males are olive-brown or olive-green. Males also have a longer tail than females. In males, the tail is 24–27% of the total body length, whereas the value for females is 21% (Wang et al. 2014).

Despite the fact snakes were found in mid-summer (late June), males attempted to mate with gravid females. Courtship behavior was observed on multiple occasions. It consisted of a male rubbing his chin along the length of a female and positioning his cloaca next to hers (Figs. 7, 8). No copulation was observed with these gravid females before oviposition. There is no documentation of other colubrids trying to copulate with gravid females nearly full term, although this is commonly observed in crotalids (Duvall et al. 1992) in which mating and birthing occur in the same season, typically fall. *Stichophanes ningshaanensis* is similar. Immediately after females laid eggs in late summer, males commence with copulation.

A clutch of eight and nine eggs was recorded from two females on 29 and 30 June 2006 (Fig. 9). The time span between successive eggs was 15 minutes, and each egg took two minutes to exit the cloaca. In the first female, after oviposition, a male immediately courted her and successfully copulated (Fig. 10).

The eggs measured 26.98 mm long and 9.52 mm wide. All 17 eggs were placed in a plastic container and covered with a damp paper towel. They were kept at room temperature (generally 24 °C but reaching a maximum of 29 °C). After 62 days, the first eggs started to pip. By 64 days all 17 eggs had pipped, and the young began to emerge from the eggs (Fig. 11).



Fig. 9. Nine eggs from a female measuring 533 mm SVL and 673 mm TL on 30 June 2006. *Photo by Kevin R. Messenger.*



Fig. 11. Hatching and emergence after 64 days of incubation. *Photo by Kevin R. Messenger.*



Fig. 13. Comparison of typical head scales and head shapes of *Oligodon* (top); 8 supralabials, 4 and 5 in contact with eye, 2 pre-oculars, 2 post-oculars, 1+2 temporals, 1 loreal, enlarged, upturned rostral scale, to the head scales of *Stichophanes* (bottom); 6 supralabials, 3 and 4 in contact with eye, 1 pre-ocular, 2 post-oculars, 1+2 temporals, no loreal, blunt rostral scale. *Photos by Kevin R. Messenger.*



Fig. 10. Copulation on 30 June 2006, post oviposition by the female. *Photo by Kevin R. Messenger.*



Fig. 12. Comparison of right maxillae; *Oligodon* on the top, with the characteristic kukri-shaped rear teeth which it uses to saw into eggs, distinguished from the anterior teeth (from Coleman et al. 1993), *Stichophanes* on the bottom, anterior teeth all the same, and a lack of rear-specialized teeth (from Wang et al. 2014).



Fig. 14. Photograph of *Pareas formosensis* (van Denburgh 1909) from Taiwan, illustrating the concave tongue notch opening that is typical of *Pareas* members. *Photo by Daniel Rosenberg.*

Comparison with Species of *Oligodon*

The genus *Oligodon* Fitzinger 1826 is a very broadly characterized genus. There are approximately 74 species within the genus as of 2013 and as such bring a wide variety of characteristics and diversity (Green 2010; Vassilieva et al. 2013). Five robust characters tend to apply to most species (Green 2010). These are:

- 1) Presence of unique posterior maxillary teeth, appearing in shape to Ghurka kukri knives, for which the genus gets its common name, “Kukri Snake.”
- 2) Large, slightly upturned rostral shield, protruding when viewed from above.
- 3) Many species possess a distinct dark chevron mark on the nape and a stripe across the anterior part of the head and down over/through the eye.
- 4) Majority of species have blotched and/or reticulate pattern, usually not prominently striped.
- 5) Most species possess a loreal scale.

Stichophanes ningshaanensis differs on several levels and conflicts with each of these five robust characters: in addition to the defensive behavioral differences mentioned previously (i.e., lack of tail curling, refusing to bite defensively), *S. ningshaanensis* does not possess the distinctive rear teeth for which *Oligodon* was named (Fig. 12). Most *Oligodon* use these specialized teeth to slice or “saw” into reptile eggs (Coleman et al. 1993). They use their upturned snout to dig up eggs, similar to species in the North American genera *Cemophora* and *Phyllorhynchus*. Once an egg is opened, they insert their head inside the egg to consume the contents. *Stichophanes ningshaanensis* lacks this upturned rostral shield, instead, having a very blunt and squared-off head (Fig. 13). Additionally, the species does not prey on eggs or

any of the known prey ingested by other *Oligodon* species but rather eats snails and slugs exclusively (Wang et al. 2014). The species lacks chevron markings on the nape and lacks a stripe across the anterior part of the head or through the eye. The species is distinctly striped and not blotched, and lastly, all specimens lack a loreal scale. From an internal perspective, the hemipene morphology does not conform to that of *Oligodon*. From a morphological and behavioral standpoint, these key differences give credence to the species not belonging to the genus *Oligodon*.

The next most likely genus for the species to be placed in, from a morphological and dietary standpoint, is *Pareas*, the Asian snail eaters.

Comparison with Asian Snail and Slug Eating Species

Due to its shortened, square head, as well as its exclusive diet of gastropods, it seems likely that *Stichophanes* could be closely related to members of the Asian snail and slug eaters: Pareatidae. Currently only three genera are known in Pareatidae. These are:

Aplopeltura: a genus containing a single species, *A. boa*, the Blunt-headed Slug Eating Snake. This genus is arboreal. The head is very distinct from the neck. This genus is located outside of China.

Asthenodipsas: a genus containing five species (Loredo et al. 2013). Members are characterized by a large head, distinct neck, lacking a mental groove, very large eyes, and an arboreal lifestyle. The mouth possesses a slotted opening that facilitates ingestion of snails and slugs. All members of the genus are located outside of China.

Pareas: a genus containing 13 species (You et al. 2015; Vogel 2015). Members are characterized by a blunt snout, lacking a mental groove, distinct neck, and no teeth on the anterior part of the maxilla (Guo and Deng 2009). The tongue notch possesses a concave opening to facilitate the ingestion of snails and slugs (Fig. 14). The majority of the species are found in China.

Stichophanes ningshaanensis does not fit into any of these genera. The species is strictly terrestrial and fossorial, there is little to no distinction between the head and neck, it possesses teeth on the anterior part of the maxilla (Fig. 12), it possesses a mental groove (Fig. 15), and does not have a slotted notch on the mouth. From a morphological, dietary, and behavioral standpoint, the species does not fit into any known Asian genus and is quite unique, not only in appearance but also in its ecology. Genetic work by Wang et al. (2014) further supported what the morphological data suggested and could not

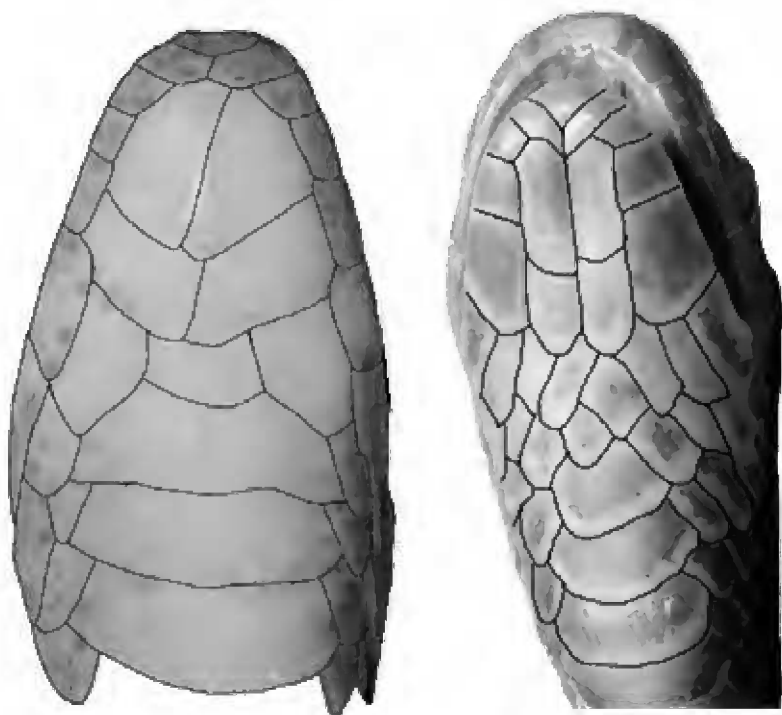


Fig. 15. Left: underside view of *Pareas vindumi* (from Vogel 2015), showing the lack of a mental groove due to asymmetrical chin shields. Right: underside view of *Stichophanes* (from Wang et al. 2014), showing symmetrical chin shields and the presence of a mental groove.



Fig. 16. Downtown Pingqian. *Stichophanes ningshaanensis* was commonly found crossing this road and in the habitat adjacent to the road. Picture taken June 2011. Photo by Kevin R. Messenger.

place the species in any known genus, at which point, a new genus was erected, *Stichophanes*.

Discussion

The purpose of this paper was to provide insight into this rarely observed and studied species. The population in the Shennongjia NNR has provided opportunities to observe several aspects of the species' natural history, from activity periods, to seasonal differences, to courtship, breeding, and incubation of eggs. The species has a unique reproductive strategy, which is not documented among other species of colubrids, or is, at the very least, quite uncommon.

Prior to 2013, the species was locally abundant in Shennongjia NNR, and specifically in Pingqian, and was among the more common and predictable species when in its habitat. The changing habitat due to development of the Pingqian village may be a turning point for the species in the area, for the worse (Figs. 16, 17). Future investigations in this area will hopefully yield knowledge on the urban tolerance (or intolerance) of the species. Investigations in 2014, despite being done during the height of the breeding season, failed to turn up a single specimen. Currently, the species is not under any special protection, currently classified as "Data Deficient." It is hoped this paper will bring us closer to understanding the species and its potential distribution, and this information will reduce the deficiency of data for this species.

Aside from the natural history aspects, another goal was to further illustrate the morphological distinction of the species from closely aligned genera, such as its original placement in *Oligodon* and its next most likely genus, *Pareas*—these differences were briefly touched on in Wang et al. (2014), and deserved greater scrutiny.

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Fig. 17. View of Downtown Pingqian in June 2014, covering same view (different angle) as Figure 16. Photo by Kevin R. Messenger.

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